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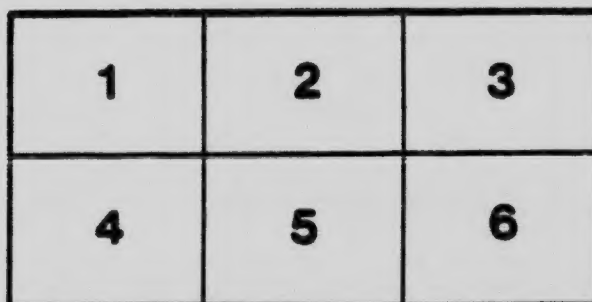
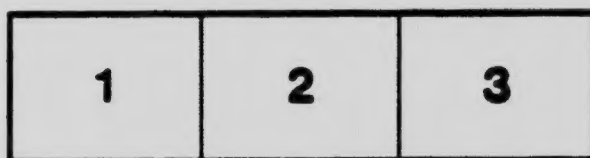
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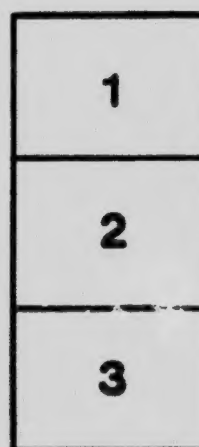
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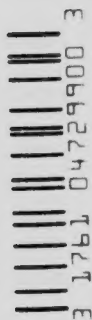
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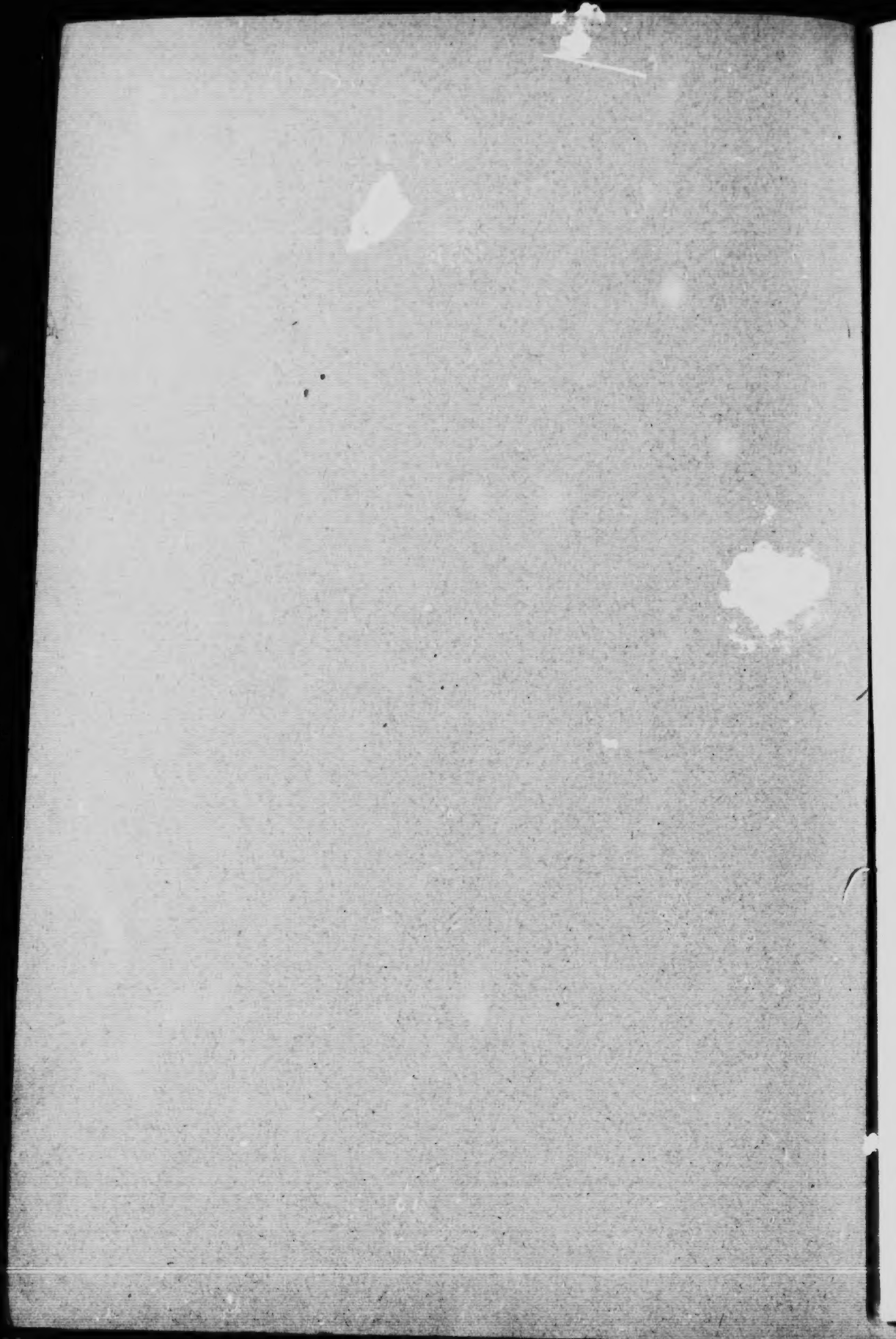
REPRINTED FROM THE JOURNAL
OF THE ROYAL ASTRONOMI-
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MAY-JUNE, 1910



SOME MEASUREMENTS OF BLENDED SPECTRA

BY

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SOME MEASUREMENTS OF BLENDED SPECTRA

BY RALPH E. DELURY

IN any source of emission or absorption of light, the conditions of the systems, whose vibrations or oscillations account for spectrum lines, are so varied that the lines are never free from the effects of blending. Furthermore, in solar and astrophysical investigations the possibility of the blending of the radiations from several sources arises. Hence it is important that the effects of blending on the measurements of the lines be known. This point was raised by me several years ago,* and the method of blending known spectra in known ways and measuring the resulting lines was suggested as a necessary step in such investigations as the determination of the rate of rotation of eclipsing variables, the presence of a haze or halo of independently moving matter between the observer and the source of light, spectroscopic binaries, etc.; and some few measurements were given of solar rotation spectra blended with sky spectrum. The following measurements of plates taken in 1911 and 1912 and measured shortly afterwards, were made in accordance with those sugges-

* Report of the Chief Astronomer, 1911, p. 281-4.

tions. Their publication has been delayed in the hope that, with the aid of certain special apparatus, the factors of photographic action, personal interpretation and characters of the spectra blended, could be thoroughly investigated; however, since the results already obtained are quite definite and seem important, they are herewith published.

The method of taking the plates was to expose for a number of seconds, l , on the limbs, using the 23 foot spectrograph with the equipment for observing the rate of the solar rotation by photographing spectra of two opposite limbs simultaneously,* then to move the sun's image so that the centre of the disc fell on the two limb windows in turn, exposing for the same time, c seconds, through each. These times are given in the following Table of Observational Data, for exposures (1) to (10). Exposure (1) is of the limbs alone: exposure (10) consists of a centre strip of spectrum from the centre of the disc, and two outside strips from the receding limb of the sun. In the first column of the table are given the numbers of the plates; in the second the position angle of the limb observations, *i. e.*, the angle between the equatorial diameter of the disc and the diameter joining the limb windows; in the third the ratio of distance of limb window from centre to radius of disc. From exposures L915 (10) and L917 (10) it is deduced that equal densities of continuous spectrum are obtained by exposures of 50 seconds from a point 0.97 of radius from centre and 21 seconds at centre; and from Abbot's "The Sun," p. 107, it follows that the intensities of these two points for $\lambda 5600$ are in the ratio 1 : 1.8. Consequently, Density = Intensity $\times$ time^{0.7} for the Cramer's Iso. Process plates used. Hence, in an exposure of l seconds, limb, followed by an exposure of c seconds, centre, the ratio of density of the continuous spectrum from the limb exposure to the total density of the exposure, is,

$$R = c_1^{0.7} \div (c_1 + c)^{0.7}, \text{ where } 1.8 c_1^{0.7} = l^{0.7} \\ = l^{0.7} \div (l + l_1)^{0.7}, \text{ where } l_1^{0.7} = 1.8 c^{0.7}.$$

* Report of the Chief Astronomer, 1900 and 1911.

For plate L854, the ratio of brightness limb (at 0.91 radius) to centre is 1:1.6; hence, in the above formula, 1.6 replaces 1.8. The values of R given in the Table of Observational Data and at the heads of columns in the subsequent tables are computed for the various degrees of blending from the above formula.

TABLE OF OBSERVATIONAL DATA

Plate	Position Angle	Limb Distance	(1) $l' \quad c'$	(2) $l \quad c$	(3) $l' \quad c$	(4) $l \quad c$	(5) $l' \quad c$	(6) $l \quad c$	(7) $l' \quad c$	(8) $l \quad c$	(9) $l' \quad c$	(10) $l \quad c$
L854	0°	0.91	40	39, 138,	236,	432,	828,	12				(not blended)
		R =	1.00	0.89	0.83	0.74	0.62	0.54				
L911	75°	0.97	50,	0.45, 3.5	40,	7.35, 10.5	30, 15.5	25, 17.5	23, 23.5	15, 24.5	10, 28	
		R =	1.00	0.89	0.79	0.69	0.58	0.51	0.43	0.33	0.24	
L912	60°	0.97	50,	3.5	50,	0.40,	7.35, 10.5	30,	14.20,	21.25, 17.5	15, 24.5	10, 28
		R =	0.90	1.00	0.79	0.69	0.60	0.42	0.51	0.33	0.24	
L913	45°	0.97	50,	0.45, 3.5	40,	7.35, 10.5	30,	14.25, 18.5	20,	21.15, 24.5	10, 28	
		R =	1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	
L914	30°	0.97	50,	0.45, 3.5	40,	7.35, 10.5	30,	14.25, 17.5	20,	21.15, 24.5	10, 28	
		R =	1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	
L915	15°	0.97	50,	0.45, 3.5	40,	7.0	35, 10.5	30, 14.0	25, 17.5	20, 21.0	15, 24.5	10, 28
		R =	1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	50 5
L917	0°	0.97	50,	0.45, 3.5	40,	7.0	35, 10.5	30, 14.0	25, 17.5	20, 21.15, 24.5	10, 28	50 20
		R =	1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	

$$R = l'07 \div (l + l_1)07 \text{ where } l_1 07 = 1.8 c'07$$

$$= c_1 07 - (c_1 + c)07, \text{ where } l'07 = 1.8 c'07$$

In making the measurements given in the following tables, the Trepfer measuring machine, (readings to 0.001 mm. and estimations to 0.0001 mm.), was used in the same way as for measuring solar rotation displacements, namely, 4 settings on the middle strip (one limb and its blend with centre spectrum), and 2 settings on each outside strip (other limb with its blend with centre). The scale of the plates is 1 A. u. = 1.42 mm. Half measured displacements and half line-widths were reduced to km./sec. by multiplying by the same factors as used in the determination of solar rotation (varying from 19.34 line 1, to 18.29 line 19). The results of L854 are given for each of the 19 spectral lines selected in the 1911 series of solar rotation plates at $\lambda 5600$, (Table 1a); and these results are given grouped as to

line intensity and line width in Table Ib; and again in Table Ic reduced to the basis: mean rotation displacement = 1.00, where the mean is determined by assigning equal weight to each line-intensity irrespective of the number of lines. Only 11 of the 19 lines, 4 to 14, were measured on plates Z911 to Z917, and these results grouped as to intensity and width of lines are given in Tables IIb to VIIb; and in Tables IIc and VIIc, reduced to the basis, mean rotation displacement = 1.00, as in Ic. Under "Line" are given the wave-length, followed by the symbol of the element producing the line from Rowland's Tables; and under intensity (presumably that of the centre of the sun's disc) as given in Rowland's Tables, followed by measures of the intensities at limb Z917 (10); in the next column are given the half-widths of the lines at centre and limb from measures of Z917 (10). Then follow the half-measurements in km./sec. Means are taken for each line and intensity (horizontally) and for each proportion of blending (vertically). In taking the means, the first and tenth columns of these measures are, of course, omitted as they are not measures of blends.

TABLE 1b

OBSERVATION—L854, (1) to (16), See Table 1a.

MEASUREMENT—See Table 1a.

COMPUTATION—Displacements of Table 1a, grouped as to Intensity and Width of Lines.

No. of Lines	Intensity		Half-Width		$R =$ 1.00	0.89	0.83	0.74	0.62	0.54	Means 0.72	Residuals
	Centre	Limb	Centre	Limb								
3	1	0	2.4	3.1	1.721	1.601	1.472	1.497	1.080	0.815	1.293	- 0.047
6	2	1	2.1	2.8	1.750	1.710	1.416	1.556	1.083	1.090	1.311	- .029
5	3	2	2.7	2.9	1.714	1.668	1.451	1.515	1.135	0.799	1.313	- .027
2	4	3	3.9	3.3	1.750	1.658	1.442	1.447	1.168	0.990	1.331	- .009
1	5	5	3.9	4.1	1.779	1.614	1.559	1.587	1.213	0.859	1.366	+ .020
1	6	6	3.6	4.0	1.779	1.642	1.660	1.600	1.231	0.865	1.380	+ .040
1	8	7	4.6	4.3	1.681	1.704	1.410	1.393	1.331	1.076	1.383	+ 0.043
Means 1.740						1.650	1.473	1.514	1.177	0.928	1.340	0.000

TABLE 1c

Displacements of Table 1b divided by 1.740.

No. of Lines	Intensity		Half-Width		$R =$ 1.00	0.89	0.83	0.74	0.62	0.54	Means 0.72	Residuals
	Centre	Limb	Centre	Limb								
3	1	0	2.4	3.1	0.99	0.92	0.85	0.86	0.62	0.47	0.74	- 0.03
6	2	1	2.1	2.8	1.01	.98	.81	.89	.62	.63	.75 +	- .02
4	3	2	2.7	2.9	0.99	.96	.84	.87	.65	.46	.76 -	- .01 +
2	4	3	3.4	3.3	1.01	.93	.83	.83	.67	.57	.77	.00
1	5	5	3.7	4.1	1.02	.95	.90	.91	.70	.49	.79 -	+ .02 -
1	6	6	3.6	4.0	1.02	.95	.90	.92	.71	.50	.79 +	+ .02 +
1	8	7	4.6	4.3	0.97	0.98	0.81	0.80	0.77	0.62	0.80	+ 0.03
Means 1.00						0.95	0.85	0.87	0.68	0.53	0.77	0.00

TABLE IIb.

OBSERVATION. *Z*911, (1) to (9), Spectra of sun's limbs at 75°, blended with spectrum at centre of disc.
 MEASUREMENT.—Red right; 4 settings middle strip, 2 settings on each outside strip.
 COMPUTATION.—Half-Displacements and half-widths of lines reduced to km. sec. Displacements grouped as to intensity and width.

No. of Lines	Intensity		Half-Width		<i>R</i> = 1.00									Means		Residuals
	Centre	Limb	Centre	Limb		0.89	0.79	0.69	0.58	0.51	0.43	0.33	0.24	0.56		
2	1	0	2.4	2.9	0.397	0.117	0.226	0.253	0.190	0.103	0.160	0.006	0.043	0.136	0.012	
3	2	1	1.9	2.5	0.411	0.225	0.126	0.175	0.122	0.118	0.016	0.047	0.010	0.101	0.047	
3	3	3	2.7	2.8	0.395	0.307	0.167	0.187	0.121	0.065	0.068	0.160	0.067	0.147	0.001	
3	4	3	3.4	3.3	0.391	0.324	0.205	0.297	0.093	0.139	0.003	0.061	0.031	0.107	+ 0.019	
1	8	7	4.6	4.3	0.275	0.332	0.307	0.359	0.240	0.067	0.111	0.029	0.002	0.188	+ 0.040	
Means 0.374						0.261	0.236	0.254	0.153	0.098	0.060	0.005	0.065	0.148	0.000	

TABLE IIc.

Displacements of Table IIb, divided by 0.374.

No. of Lines	Intensity		Half-Width		<i>R</i> = 1.00									Means		Residuals
	Centre	Limb	Centre	Limb		0.89	0.79	0.69	0.58	0.51	0.42	0.33	0.24	0.56		
2	1	0	2.4	2.9	1.06	0.31	0.60	0.63	0.51	0.28	0.43	0.02	0.16	0.36	- 0.04	
3	2	1	1.9	2.5	1.10	0.60	0.33	0.47	0.32	0.31	0.04	0.13	0.03	0.27	- 0.13	
3	3	3	2.7	2.8	1.06	0.82	0.45	0.50	0.32	0.17	0.18	0.51	0.18	0.39	- 0.01	
3	4	3	3.4	3.3	1.05	0.87	0.74	0.80	0.25	0.37	0.25	0.16	0.08	0.45	+ 0.05	
1	8	7	4.6	4.3	0.74	0.89	0.98	0.96	0.64	0.18	0.30	0.08	0.01	0.50	+ 0.10	
Means 1.00						0.70	0.63	0.68	0.41	0.26	0.24	0.17	0.08	0.40	0.00	

TABLE IIIb.

OBSERVATION--Z912, (1) to (9), Spectra of sun's limbs at 60°, blended with spectrum of centre of disc.

MEASUREMENT--Red right; 4 settings middle strip, 2 settings on each outside strip.

COMPUTATION--Half-Displacements and half-widths of lines reduced to km. sec. Displacements grouped as to intensity and width.

No. of Lines	Intensity		Half-Width		R =		0.89		0.79		0.69		0.60		0.51		0.42		0.33		0.24		Means		Residuals	
	Centre	Limb	Centre	Limb	1.00																		0.56		0.56	
2	1	0	2.4	2.9	0.582	0.574	0.491	0.203	0.218	0.110	0.074	0.007	0.110	0.042	0.207	-0.042							0.207	-0.042		
3	2	1	1.9	2.5	0.611	0.608	0.525	0.258	0.176	0.064	0.116	0.037	0.111	0.027	0.222	-0.027							0.222	-0.027		
3	3	3	2.7	2.8	0.618	0.602	0.451	0.353	0.188	0.138	0.133	0.000	0.07	0.017	0.232	-0.017							0.232	-0.017		
2	4	3	3.4	3.3	0.510	0.447	0.532	0.492	0.085	0.263	0.000	0.08	0.35	0.035	0.350	-0.035							0.350	-0.035		
1	8	7	4.6	4.3	0.501	0.615	0.503	0.607	0.426	0.292	0.181	0.169	0.000	0.101	0.350	-0.101							0.350	-0.101		
Means					0.565	0.569	0.500	0.383	0.219	0.173	0.000	0.000	0.33	0.000	0.249	-0.000							0.249	-0.000		

TABLE IIIc.

Displacements of Table IIIb, divided by 0.565.

No. of Lines	Intensity		Half-Width		R =		0.89		0.79		0.69		0.60		0.51		0.42		0.33		0.24		Means		Residuals	
	Centre	Limb	Centre	Limb	1.00																		0.56		0.56	
2	1	0	2.4	2.9	1.03	1.02	0.87	0.36	0.39	0.19	0.13	0.17	0.19	0.07	0.37	-0.07							0.37	-0.07		
3	2	1	1.9	2.5	1.08	1.05	0.81	0.46	0.31	0.11	0.21	0.07	0.11	0.02	0.39	-0.02							0.39	-0.02		
3	3	3	2.7	2.8	1.09	1.07	0.80	0.62	0.33	0.24	0.23	0.00	0.01	0.03	0.41	-0.01							0.41	-0.03		
2	4	3	3.4	3.3	0.90	0.79	0.94	0.87	0.15	0.47	0.12	0.30	0.06	0.03	0.62	-0.06							0.62	-0.03		
1	8	7	4.6	4.3	0.89	1.09	0.89	1.07	0.75	0.52	0.32	0.30	0.00	0.18	0.62	-0.00							0.62	-0.18		
Means					1.00	1.01	0.89	0.68	0.39	0.31	0.20	0.11	0.06	0.00	0.44	-0.06							0.44	-0.00		

TABLE IVb.

OBSERVATION Z913, (r) to (9), Spectra of sun's limbs at 45°, blended with spectrum from centre of disc.
 MEASUREMENT - Red right; 4 settings middle strip, 2 settings on each outside strip.
 COMPUTATION - Half-Displacements and half-widths of lines reduced to km./sec. Displacements grouped as to intensity and width.

No. of Lines	Intensity		Half-Width		$R =$ 1.00	$R =$							Means 0.56	Residuals	
	Centre	Limb	Centre	Limb		0.89	0.79	0.69	0.60	0.51	0.42	0.33			0.24
2	1	0	2.4	2.9	1.078	0.821	0.622	0.373	0.343	0.254	0.113	0.025	0.016	0.315	- 0.092
3	2	1	1.9	2.5	1.126	0.853	0.554	0.405	0.441	0.187	0.145	0.085	0.023	0.337	- 0.070
3	3	3	2.7	2.8	1.064	0.932	0.697	0.418	0.287	0.290	0.192	0.132	0.055	0.382	- 0.025
2	4	3	3.4	3.3	1.037	0.896	0.737	0.535	0.307	0.320	0.176	0.111	0.211	0.412	- 0.005
1	8	7	4.6	4.3	1.139	1.035	0.832	0.569	0.728	0.536	0.478	0.376	0.148	0.588	+ 0.181
Means					1.088	0.917	0.688	0.460	0.421	0.317	0.221	0.136	0.091	0.407	0.000

TABLE IVc.

Displacements of Table IVb, divided by 1.088.

No. of Lines	Intensity		Half-Width		<i>R</i> 1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	Means 0.56	Residuals
	Centre	Limb	Centre	Limb											
2	1	0	2.4	2.9	0.99	0.75	0.57	0.34	0.32	0.23	0.10	0.02	0.01	0.29	0.08
3	2	1	1.9	2.5	1.04	0.78	0.51	0.37	0.40	0.17	0.13	0.08	0.02	0.31	0.00
3	3	3	2.7	2.8	0.98	0.90	0.64	0.38	0.26	0.27	0.18	0.12	0.05	0.35	-0.02
3	3	3	3	3	0.95	0.82	0.68	0.49	0.28	0.29	0.16	0.10	0.19	0.38	-0.01
2	4	3	3.4	3.3	0.95	0.82	0.68	0.49	0.28	0.29	0.16	0.10	0.19	0.38	-0.01
1	8	7	4.6	4.3	1.04	0.95	0.76	0.52	0.67	0.49	0.44	0.35	0.14	0.54	+0.17
Means					1.00	0.84	0.63	0.42	0.39	0.29	0.20	0.12	0.08	0.37	0.00

TABLE Vb.

OBSERVATION--Z912, (1) to (9), Spectra of sun's limbs at 30°, blended with spectrum of centre of disc.

MEASUREMENT - Red right; 4 settings middle strip, 2 settings on each outside strip.

COMPUTATION-- Half-Displacements and half-widths of lines reduced to km. sec. Displacements grouped as to intensity and width.

No. of Lines	Intensity Centre	Limb	Half-Width		R =	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	Means 0.56	Residuals
			Centre	Limb											
2	1	0	2.4	2.9	1.273	1.118	0.768	0.471	0.237	0.311	0.104	0.049	-0.040	0.379	-0.110
3	2	1	1.9	2.5	1.369	1.190	.554	.531	.306	.106	.067	.158	-0.30	.40	-.080
3	3	3	2.7	2.8	1.367	1.197	.992	.572	.400	.267	.079	.192	-.062	.455	-.034
2	4	3	3.4	3.3	1.400	1.249	.871	.742	.460	.308	.158	.182	-0.07	.495	+.066
1	8	7	4.6	4.3	1.366	1.239	1.058	0.955	0.728	0.586	0.513	0.386	+0.184	0.706	+0.217
Means					1.347	1.201	0.909	0.654	0.426	0.334	0.184	0.193	0.000	0.484	0.000

TABLE Vc.

Displacements of Table Vb. divided by 1.347.

No. of Lines	Intensity Centre	Limb	Half-Width		R =	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	Means 0.56	Residuals
			Centre	Limb											
2	1	0	2.4	2.9	0.95	0.84	0.57	0.35	0.18	0.23	0.08	0.04	-0.33	0.28	-0.08
3	2	1	1.9	2.5	1.03	.88	.63	.39	.23	.15	.05	.12	-0.02	.30	-.06
3	3	3	2.7	2.8	1.01	.89	.74	.42	.30	.20	.06	.14	-0.05	.34	-.02
2	4	3	3.4	3.3	1.04	.93	.65	.55	.34	.23	.12	.13	-0.01	.37	+.01
1	8	7	4.6	4.3	0.97	0.92	0.78	0.71	0.54	0.44	0.38	0.29	+0.14	0.52	+0.16
Means					1.00	0.89	0.67	0.49	0.32	0.25	0.14	0.14	0.46	0.30	0.00

TABLE VIb.

OBSERVATION—L915, (1) to (10), Spectra of sun's limbs at 15°, blended with spectrum from centre of disc.

MEASUREMENT—Red right; 4 settings middle strip, 2 settings on each outside strip.

COMPUTATION—Half-Displacements and half-widths of lines reduced to km. sec. Displacements grouped as to intensity and width.

No. of Lines	Intensity Centre Lamb	Half-Width Centre Lamb	R =										Means and	Residuals
			1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	0.00		
2	1	0	1.729	1.582	1.073	0.670	0.409	0.061	0.051	-0.014	-0.027	1.026	0.474	-0.081
3	2	1	1.866	1.405	1.114	.531	.453	.142	.075	.047	.083	.927	.461	-.034
3	3	3	1.764	1.640	1.145	.733	.547	.208	.067	-.033	.101	.886	.526	-.029
(2)	4	3	1.742	1.280	1.280	(.841)	.557	.466	.097	.010	.001	.898	1.559	+ .004
1	8	7	1.773	1.802	1.590	0.970	0.686	0.570	0.292	0.173	0.040	0.962	0.755	+ 0.200
Means			1.775	1.542	1.240	0.740	0.630	0.277	0.116	0.037	0.050	0.949	0.555	0.000

TABLE VIc.

Displacements of Table VIb. divided by 1.775.

No. of Lines	Intensity Centre Lamb	Half-Width Centre Lamb	R =										Means and	Residuals
			1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	0.00		
2	1	0	0.97	0.89	0.60	0.38	0.23	0.03	0.03	-0.01	0.02	0.58	0.27	-0.04
3	2	1	1.05	.63	.30	.26	.08	.04	.04	.03	.05	.52	.26	-.05
3	3	3	0.95	.65	.41	.31	.12	.04	.04	.02	.06	.50	.30	-.01
(2)	4	3	0.98	(.72)	(.47)	.31	.23	.05	.05	.01	.00	.51	1.321	+ .01
1	8	7	1.00	1.02	0.99	0.55	0.39	0.32	0.16	0.10	0.02	0.54	0.43	+ 0.12
Means			1.00	0.87	0.70	0.42	0.35	0.10	0.07	0.02	-0.03	0.53	0.31	0.00

TABLE VIIb.

OBSERVATION.—Z917, (1) to (10), Spectra of sun's limbs at α° , blended with spectrum of centre of disc.

MEASUREMENT.—Red right: 4 settings middle strip, 2 settings on each outside strip.

COMPUTATION.—Half-Displacements and half-widths of lines reduced to km. sec. Displacements grouped as to intensity and width.

No. of Lines	Intensity Centre Limb	Half-Width Centre Limb	R =										Means and 0.56	Residuals
			1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	0.10		
2	1	0	1.776	1.414	1.115	0.493	0.529	0.205	0.436	0.085	0.063	0.897	0.543	- 0.080
3	2	1	1.725	1.636	1.071	.600	.505	.074	.269	.000	.114	.049	.534	- .089
3	3	3	1.691	1.413	1.030	.682	.647	.115	.385	.093	.119	.037	.501	- .062
2	4	3	1.926	1.686	1.148	.792	.663	.300	.459	.071	.144	.939	.058	+ .035
1	8	7	1.583	1.583	1.538	0.943	1.062	0.417	0.620	0.057	0.119	0.786	0.817	+ 0.194
Means			1.740	1.546	1.180	0.702	0.681	0.222	0.434	0.101	0.112	0.901	0.923	0.000

TABLE VIIc.

Displacements of Table VIIb. divided by 1.740.

No. of Lines	Intensity Centre Limb	Half-Width Centre Limb	R =										Means and 0.56	Residuals
			1.00	0.89	0.79	0.69	0.60	0.51	0.42	0.33	0.24	0.10		
2	1	0	1.02	0.81	0.64	0.28	0.30	0.12	0.25	0.05	0.04	0.52	0.31	- 0.05
3	2	1	0.99	.94	.62	.34	.29	.04	.15	.00	.07	.55	.30	- .09
3	3	3	0.97	.81	.59	.39	.37	.06	.22	.05	.07	.54	.32	- .04
2	4	3	1.11	.97	.66	.45	.38	.17	.26	.04	.08	.54	.38	+ .02
1	8	7	0.91	0.91	0.88	0.54	0.61	0.24	0.36	0.15	0.07	0.45	0.47	+ 0.11
Means			1.00	0.89	0.68	0.40	0.39	0.13	0.25	0.06	0.06	0.52	0.36	0.00

TABLE VIIIb.

Summary of Plates L911 to L917, means grouped as to intensity and width of lines.

No. of Lines	Intensity		Half-Width		$R =$ 1'00	0'79	0'69	0'60	0'51	0'42	0'33	0'24	Means	Residuals
	Centre	Limb	Centre	Limb										
2	1	0	2'4	2'9	1'139	0'939	0'716	0'411	0'321	0'174	0'156	0'009	0'343	- 0'069
3	2	1	1'9	2'5	1'188	0'980	0'707	0'417	0'334	0'130	0'100	0'004	0'344	- 0'018
3	3	2	2'8	3'1	1'150	0'924	0'747	0'401	0'305	0'151	0'154	0'012	0'384	- 0'028
2	4	3	3'4	3'3	1'168	0'980	0'811	0'617	0'361	0'289	0'175	0'061	0'421	+ 0'009
2	5	4	4'6	4'3	1'181	1'101	0'981	0'734	0'645	0'411	0'300	0'009	0'597	+ 0'155
1	8	7											0'412	0'009
			Means		1'165	1'000	0'792	0'534	0'405	0'237	0'192	0'030		

TABLE VIII.

Mean displacements of Table VIII, divided by 1.165.

No. of Lines	Intensity		Half-Width Centre Limb	R 1·00	0·89	0·79	0·69	0·60	0·51	0·42	0·33	0·24	Means 0·56	Residuals
	Centre Limb	Centre Limb												
2	1	0	2·4	0·98	0·81	0·61 +	0·35	0·28	0·15	0·13	0·03	0·01	0·29	- 0·06
3	2	1	2·5	1·02	0·85	0·61 -	0·30	0·29	0·11	0·09	0·05	0·00	0·29	- 0·00
3	3	1	2·8	0·90	0·88	0·64	0·42	0·31	0·16	0·13	0·08	0·01	0·33	0·02
3	3	3	3	1·00	0·84	0·70	0·53	0·31	0·25	0·15	0·09	0·05	0·30	0·01
2	4	3	3·4	1·00	0·84	0·70	0·53	0·31	0·25	0·15	0·09	0·05	0·30	0·01
1	8	7	4·0	1·01	0·95	0·84	0·63	0·55	0·35	0·31	0·20	0·00	0·49	+ 0·14
			4·3											
			Means	1·00	0·86	0·68	0·40	0·35	0·20	0·16	0·08	0·02	0·35	0·00

TABLE IX.

Plates	Rotation Displacements	Proportionate Rotation Displacements for Intensities					Mean
		1	2	3	4	8	
L911	0.374	0.36	0.27	0.39	0.45	0.50	0.40
L912	0.505	0.37	0.30	0.41	0.41	0.62	0.44
L913	1.088	0.29	0.31	0.35	0.38	0.54	0.37
L914	1.347	0.28	0.30	0.34	0.37	0.52	0.30
L915	1.775	0.27	0.26	0.30	0.32	0.43	0.32
L917	1.740	0.31	0.30	0.32	0.38	0.47	0.30
							0.37

TABLE X.

I	c	Intensity 1		Intensity 2		Intensity 3		Intensity 4		Intensity 8		Mean	
		d	k	d	k	d	k	d	k	d	k	d	k
45	3.5	0.81	1.1	0.85	1.3	0.88	1.1	0.84	1.4	0.95	0.7	0.86	1.1
40	7.0	.91	1.9	.91	1.9	.94	1.7	.70	1.4	.84	0.8	.68	1.5
35	10.5	.95	3.1	.90	3.0	.42	2.4	.53	1.7	.93	1.2	.46	2.1
30	14.0	.28	3.0	.20	2.0	.31	2.0	.31	2.0	.55	1.2	.35	2.2
25	17.5	.15	4.5	.11	6.3	.16	4.2	.25	2.5	.35	1.7	.20	3.3
20	21.0	.13	4.0	.00	5.8	.15	4.0	.15	3.4	.31	1.5	.16	3.2
15	24.5	.03	13.1	.05	7.8	.08	4.8	.00	6.5	.20	1.8	.08	4.8
10	28.0	0.01		0.00		0.01	27	0.05	5.3	0.06	3.2	0.02	13.5
Interpolated		0.50	2.4	0.50	2.3	0.50	2.0	0.50	1.8	0.50	1.3	0.50	2.0

TABLE XI.

I	c	Intensity 1		Intensity 2		Intensity 3		Intensity 4		Intensity 8		Mean	
		d	R ₁	d	R ₁	d	R ₁	d	R ₁	d	R ₁	d	R ₁
45	3.5	0.81	0.71	0.85	0.72	0.88	0.76	0.84	0.78	0.95	0.85	0.86	0.76
40	7.0	.91	.54	.91	.55	.94	.60	.70	.93	.84	.72	.68	.60
35	10.5	.95	.42	.90	.44	.42	.48	.53	.51	.93	.61	.46	.48
30	14.0	.28	.33	.20	.35	.31	.30	.31	.42	.55	.52	.35	.39
25	17.5	.15	.27	.11	.27	.16	.31	.25	.34	.35	.43	.20	.31
20	21.0	.13	.21	.00	.22	.13	.24	.15	.27	.31	.35	.16	.24
15	24.5	.03	.16	.05	.16	.08	.18	.06	.20	.20	.27	.08	.18
10	28.0	0.01	0.11	0.00	0.11	0.01	0.13	0.05	0.14	0.06	0.10	0.02	0.13

A glance at Table Ia. suffices to show that the measured displacements of the blended spectrum lines vary greatly from line to line, being greater as the intensity or width of the line increases. This is shown more positively when the lines are grouped as to intensity and width in Table Ib. and reduced to the unity basis in Table Ic., where also a comparison is readily made with the values of R .

Plates Z911 to Z917 cover a considerable range of displacements and of proportions of blending. The measurements of these plates — displacements grouped as to intensity and width, Tables IIb. to VIIb. — show the same dependence of the measures on intensity. Tables IIc. to VIIc. reduced to the basis, rotation displacement = 1.00, are more readily compared with one another. Summarizing the means of the different plates, Table IX., it is seen that there is very little dependence of the proportionate displacements on the initial (rotation) displacement; possibly a slight tendency to smaller proportionate displacements as the initial displacement is increased. This absence of variation of proportionate displacement with initial displacement is, no doubt, due to the fact that the greatest displacement, 2×1.78 km./sec., is only about half of the average width of lines, 2×3 km./sec. Increasing the initial displacements further, (which is, of course, impossible in this case, being restricted by the speed of the sun's rotation), would undoubtedly show greater effect on the measured proportionate displacements. Width of line would then become a more important factor. Since the proportionate values of the measurements do not depend on the initial displacement, the summary of the means of Plates Z911 to Z917, for the various proportions of blending of centre and limb spectra, Table VIIIb., and their proportionate values, Table VIIIc., may be taken as representative of all measures in the discussion which follows.

The values of Table VIIIc. are plotted in Figure 1, proportionate displacements, d , plotted vertically and values of R , (*i. e.*, ratio of density of continuous spectrum of limb exposure to density of the continuous spectrum in total exposure), plotted

horizontally. Now an obvious reason to account for the different values of d for various lines is the fact that the ratio of intensity of the centre lines to the intensity of the limb lines varies for different lines. We would expect that if spectra of equal intens-

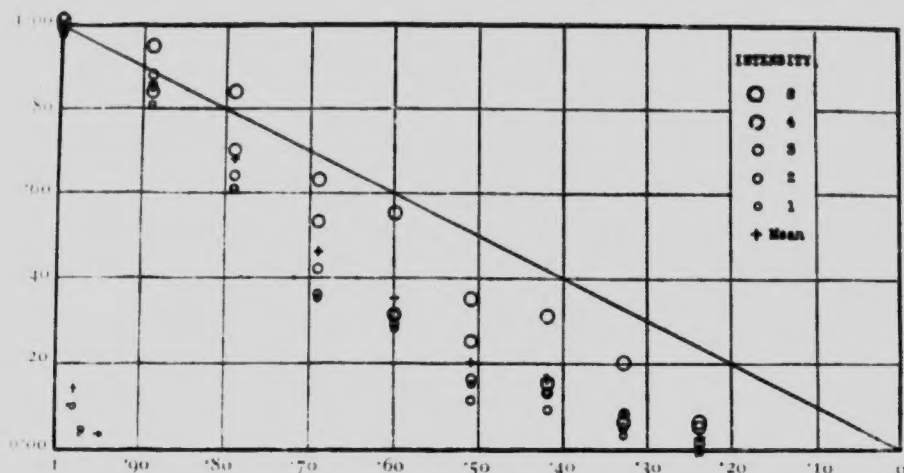


FIGURE 1.

ity—lines not continuous spectrum—were blended, the value of d would be 0.50; especially as errors of interpretation and photographic effect would be annulled in its measurement. In computing R we have,

$$R = c_1^{0.7} / (c_1 + c)^{0.7}, \text{ where } l^{0.7} = 1.8 c_1^{0.7},$$

l and c being the times of exposure on limb and then centre, and 1.8 is the ratio of intensity of limb continuous spectrum to centre continuous spectrum. In computing R_1 for any line, however,

$$R_1 = c_1^{0.7} / (c_1 + c)^{0.7}, \text{ where } l^{0.7} = 1.8 k c_1^{0.7},$$

where k = ratio of intensity of centre line to corresponding limb line. Consequently, assuming that $R_1 = d$ for each line, k can be found. These values of k are given in Table X. The values of k are seen to vary considerably for the different degrees of blending, pointing to a cause other than the difference in intens-

ity of the lines in centre and limb. However, it seems safe to assume that this cause is inoperative for values of $d = 0.50$ in each case; so that we may take the values of k interpolated for $d = 0.50$ as representing the true ratio of centre line to limb line. Rough visual determinations agree with these values of k . Using these values of k the values of R_l , Table XI., are found. Now plotting d and R_l , Figure 2, we see that the curve of observations, nearly the same for each line, swings symmetrically above

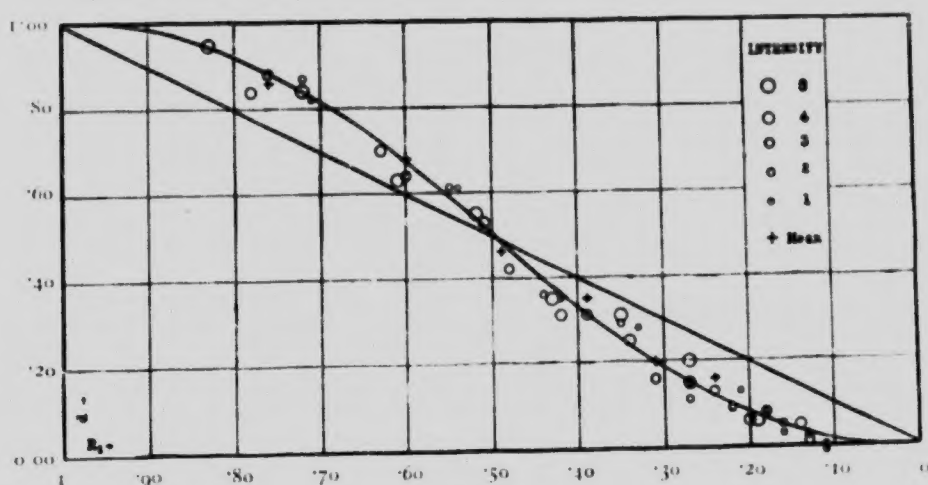


FIGURE 2.

and below the line $d = R_l$. The measurements thus exhibit some tendency common to all lines, possibly due to photographic action but more probably due to interpretation of the blends, *i. e.*, when strong and weak spectra are blended one's measurements tend to give proportionately greater weight to the stronger spectrum. This is in agreement with my measures of the blending of sky spectrum with sun rotation spectra in which the lower proportions of blending showed no appreciable effect of the sky spectrum.

The results found above are applicable to the interpretation of certain peculiarities found in the spectroscopic study of double

stars, the comparison of velocities of stars of different type, and other astrophysical problems; but I shall not discuss these points here. The results are applicable directly to the problem of the determination of the rate of the sun's rotation; in fact the above work was undertaken primarily in the hope that it would offer an explanation of the difference in the rate of the sun's rotation as determined from different spectrum lines (as announced by Adams for his determinations of 1906-1908), and possibly of the greater polar retardation from the spectroscopic observations than from the spots and faculae. Adams' results have recently been verified by himself and St. John at Mt. Wilson in a manner that leaves little room for doubt as to their accuracy, though for the period 1911-1913 several other observers found little or no trace of the effect. The assumption of blended spectra during the time of sun-spots and an absence of the effect when the spots are absent offers an explanation of the above observations, but the point will be discussed soon in a separate paper.

The main conclusions of the above work are:

In the measurements of photographs of blended spectra the stronger spectrum asserts itself out of proportion to the relative intensities of the lines measured, the effect being more pronounced the greater the difference in the intensities of the components of the blends.

When spectra, in which the lines have different character and are displaced by amounts ranging up to half the widths of the lines in question, are blended, the measurements of the resulting lines vary from line to line as the relative intensities vary. In the case of blending the sun's limb (lines displaced by rotation) and centre (lines not displaced) spectra, since the relative intensities of lines progresses fairly regularly with intensity (*i. e.*, level in the sun) the measured displacements of the blends progress regularly. In other words, lines of different intensity show different velocities of rotation, the strong lines showing progressively greater values than the weak lines; and since this very effect has been found by some observers in the determination of the sun's rate of rotation it is suggested that at

the time of their observations the limb spectra were blended with spectra in which the lines were less displaced or not displaced at all, such as a strong sky spectrum or spectrum from independently moving matter outside the sun or matter just freshly fallen into the sun and not sharing completely its rotation.

DOMINION OBSERVATORY,

OTTAWA, CANADA.

February, 1916.